IN-PROCESS ASSESSMENT OF DRESSING CONDITION DURING SURFACE GRINDING

By
ALOK SHRIVASTAVA

DEPARTMENT OF MECHANICAL ENGINEERING
INDIAN INSTITUTE OF TECHNOLOGY, KANPUR

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ALOK SHRIVASTAVA

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DEDICATED TO

MY LATE FATHER

AND

MY MOTHER WHO HAS BEEN A PILLAR OF STRENGTH
OFFERING HER CHILDREN SUPPORT AND LOVE AND
WHO HAS MADE ME WHAT I AM TODAY

CERTIFICATE

This is to certify that the work entitled, " IN-PROCESS ASSESSMENT OF DRESSING CONDITION DURING SURFACE GRINDING" has been carried out by Alok Shrivastava under my supervision and has not been submitted elsewhere for the award of a degree.

27/4/85

DR. G.S. KAINTH
Professor
Department of Mechanical Engg.
Indian Institute of Technology
Kanpur-208016

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APRIL, 1985 ALOK SHRIVASTAVA

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NOMENCLATURE

D	Depth of cut, micron
V	Grinding wheel speed, rpm
v	Table speed m/min
PSD	Power spectral density
f	Frequency Hz
w	Width of wear flat
u_o	Wavelength at which the power spectrum pattern falls to zero
I	Intensity, mV
N	Number of passes

ABSTRACT

Experiments are carried out under plunge cut up-grinding condition on mild steel using horizontal surface grinding machine.

An accelerometer is attached to the workpiece to measure the random vibration signal in the tangential direction. Signal analyzer is used to determine the power spectral density of the vibration signal.

Topography of the grinding wheel is determined by laser technique using the power spectrum pattern obtained from the grinding wheel surface.

The variation of peak power spectral density with number of passes, for different depth of cut is discussed. The variation of intensity and width of wear flat with number of passes is also discussed.

The present investigation shows that the wheel wear has significant effect on the power spectral density of the signal, which is affected by amplitude of vibration. Furthermore, it is possible to predict the redressing condition of the wheel from the measurement of the

spectral density as well as by the topography of grinding wheel surface.

Present study shows the feasibility of in-process monitoring of vibration signals and grinding wheel surface in the surface grinding process which can be used for adaptive control of the process.

CHAPTER-1

INTRODUCTION AND REVIEW OF PREVIOUS WORK

1.1 INTRODUCTION:

Grinding is an operation in which material is removed from workpiece with randomly spaced abrasive grains bonded in a grinding wheel. In recent years grinding has received a great attention because of ever increasing trend towards high precision in machining of high strength materials. Grinding is generally used for obtaining close tolerances and high quality of surface finish on workpiece.

There are several types of grinding operations i.e. surface grinding, internal or cylindrical grinding, external grinding centreless grinding and off-hand grinding.

Grinding wheel is composed of a large number of small abrasive particles held togather by a bonding agent. The performance of a grinding wheel depends upon a large number of variables such as type of abrasive grains, grain size, hardness of wheel, structure of the wheel,

type of bond and cutting conditions. These parameters can be chosen to obtain a wide range of wheel types for specific applications.

Majority of grinding wheels are made from either aluminium oxide or silicon carbide abrasive. The grade or hardness of a wheel indicates the relative strength of bond which holds the abrasive grains in place. The structure of the grinding wheel denotes the spacing between the grains and controls the density of the wheel. Grinding wheel has intergranular spaces which help to clear the wheel face from the metal surface and accommodate the chips removed by the abrasive grains.

During grinding the cutting edge of abrasive grains and the workpiece are in a state of physical contact with each other. The work surface attains a high temperature (600-700°C). Due to excessive wear of grains and high friction, the temperature reaches a value where the formation of austenite takes place on the work surface and brownish spots are seen on the surface resulting in burn-off.

Under certain conditions metallic chips get embedded into the wheel causing wheel loading. Loading generally occurs while grinding soft or tough materials with hard wheel or using light cutting conditions.

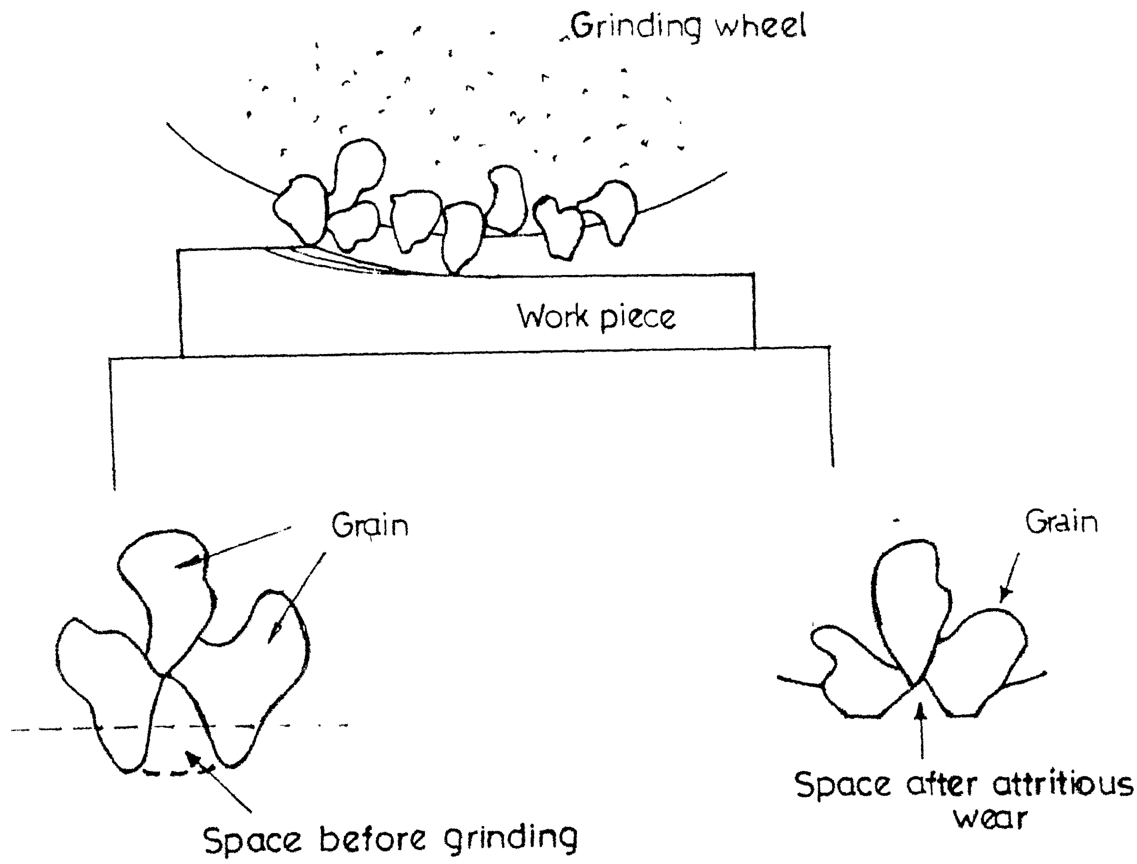

FIG1A ATTRITIOUS WEAR AND LOADING

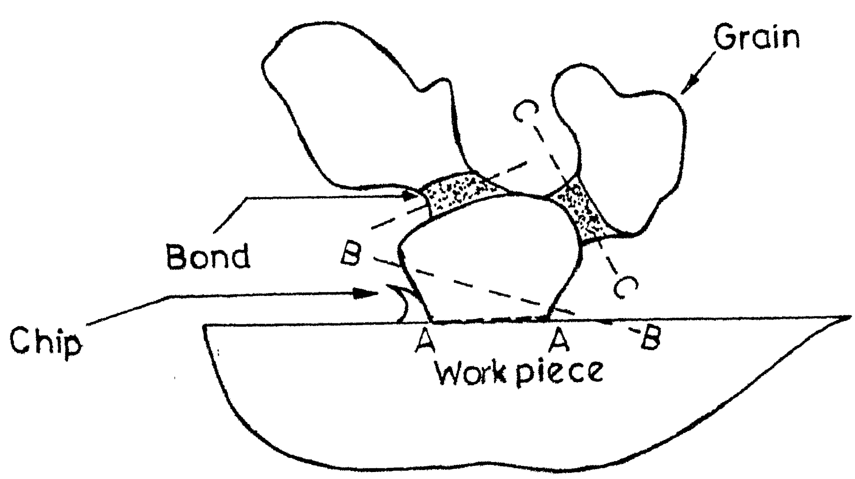

FIG1B ILLUSTRATION OF THREE TYPES OF WEAR
AA—Attritious wear ; BB—Grain fracture
CC—Bond fracture

Loading interferes with free cutting, resulting in excessive heating of the workpiece that results in deterioration of the surface finish.

Wear of the grinding wheel is an integral part of the process, there are two types of wheel wear (i) Attritious wear (ii) Fracture wear. Attritious wear (Fig. 1.1a) occurs due to formation of flat areas on the grains, and accounts for glazed appearance on the wheel which produces excessive friction at contact surface. The cutting ability of the grinding wheel is restored by dressing the wheel. Fracture wear (Fig. 1.1b) is due to removal of abrasive grains from the wheel either by particle fracture of grains or by fracturing of bond post. This type of wear maintains the cutting ability of the wheel by presenting sharp cutting edges without the need for dressing.

During grinding, the relative vibrations between the grinding wheel and the workpiece cause deterioration of surface finish and reduce the life of grinding wheel. These vibrations are of two types.

(1) Forced vibrations caused by unbalance either in grinding wheel or in gearing system. These vibrations can be controlled by careful design and balancing.

(2) Chatter vibrations are produced by inhomogenity of surface structure of wheel and "regenerative effect". The regenerative effect [1] is produced when a 'bump generated during one revolution of the wheel (random vibrations generate this first bump) will tend to kick the system during another revolution. Moreover this first kick will tend to generate more jolts on subsequent wheel revolution'.

The result of these vibrations is eventually reflected on the surface of the grinding wheel. As more jolts are generated, a series of bumps or lobes appear on the wheel and grow in an orderly manner. These lobes may accompany chatter and may produce a rough surface even in the absence of chatter. Furthermore, the wheel wear lobes tend to precess or "walk" around the wheel during the grinding process. The rate of precession is directly related to wear of the grinding wheel. [1]

1.2 LITERATURE SURVEY:

1.21 Wear of Grinding Wheels:

Shaw and Lal [2] studied the wear of single abrasive grains. The grains were tested in a fly milling situation in which grains were mounted on the periphery of a metal disc which was used in place of a grinding wheel. Wear rate was found to be directly proportional

to the length of cut and it increases with increasing workpiece hardness, wheel speed and undeformed chip thickness.

Pande and Lal [3] studied the wear phenomena accompanying dry surface grinding of mild steel under plunge conditions from the force pattern, grinding ratio and wear particle size removed from the wheel.

Yoshikawa and Sata [4] developed an expression between probability of fracture of abrasive grains, stress induced and loading time. They performed experiments under surface grinding condition and concluded that wear rate of the grinding wheel can be expressed as single exponential function of the grinding speed and as the double exponential function of grinding force.

Malkin and Cook [5] investigated the nature and extent of grinding wheel wear. A statistical analysis of wear particle size distribution was developed to determine the relative amounts of bond fracture, grain fracture and attritious wear. Most of the wear consists of grain and bond fracture particles with relatively more bond fracture occurring with softer wheels. The rate at which fracture wear occurs is directly related to grinding force and amount of binder in the wheel. The attritions wear, although, contributing insignificantly to the total wear, is the most important from the point of view of size of wear flats, grinding force and workpiece burn-off.

Lal and Stetiu [6] studied wear phenomena from the wear particles removed from the wheel in cylindrical grinding. Self dressing mechanism was identified from wear particle size distribution. It was concluded that the hardness of the grinding wheel is the most important property affecting the wear phenomenon. By using a softer wheel, mechanism of wheel wear can be changed from attritious to fracture wear.

1.22 Loading of the Grinding Wheel:

Konig and Aacheu [7] studied the loading phenomenon of the grinding wheel and measured the loading by using new inductive sensor. It was concluded that the chips in the grinding wheel will alter the grain edge geometry and friction process occurring during the operation whenever the grinding wheel structure is unable to cope with the quantity of chips removed from the work surface. The loaded wheel will now result in increased cutting forces and power consumption which, in turn, may lead to a breakdown of the grinding wheel.

1.23 Dressing of Grinding Wheel:

Kaliszer and Tremel [8] discussed the effect of dressing upon the grinding performance. Various methods of dressing such as abrasive dressing, crush dressing and diamond dressing, have been described in detail.

It was also pointed out that the dressing technique not only affects the initial stages of grinding but it also affects the performance during the whole life of the wheel between two dressing operations.

Fletcher [9] showed the importance of selection of dressing variables. Cross feed and diamond geometry were found to have greatest influence on the surface finish. Whereas, depth of cut was of secondary importance.

Yerkerk [10] discussed the effect of dressing conditions on the distribution of metal removal rate over the wheel surface. A new method of dressing is proposed which has the advantage of fine dressing (good surface finish) and coarse dressing (increased cutting performance and decreased risk of thermal damage) with same metal removal rate.

Matsni and Ryozo [11] suggested a new criterion for the wheel redressing life in fine cylindrical grinding. In most cases of dressing using a single point diamond dresser, a thread is generated on the wheel face which changes its form with lapse of grinding time. After some time the same thread is generated over the workpiece surface. Changes in the ground surface profile with lapse of grinding time are persued by means of spectrum analysis and from the disappearance of the thread on the work

surface it is concluded that wheel has just reached its redress life.

1.24 Wheel Condition:

Toshio and Suto [12] made inprocess measurement of several important quantities such as location and size of active cutting edges on the surface of grinding wheel, volumetric wear of grinding wheel, ground volume of work material, loading of work material, and grinding force. The flattened area of active grains was observed by detecting reflected light from the surface of grinding wheel. In process measurement of volumetric wear of a grinding wheel was made with floating air nozzle. Air gap between nozzle and mean wheel surface was automatically made constant and displacement of nozzle due to wear was measured by differential transformer. An eddy current sensor mounted close to wheel surface measured the amount of ground chips.

Hamed, et al. [13] used the auto correlation function to monitor the behaviour of abrasive grains. Shape of the auto correlation was related to different grit sizes and it was concluded that shape of A.C. function and correlation length depend critically on the grit size. Relationship of grit size and the correlation length was found to be negative exponential.

Radhakrishanan [14] studied the condition of grinding wheel from dressed to glazed wheel by turbulance amplifier. Marked difference in air velocity and intensity of turbulance is noticed from dressed loaded and glazed wheel.

Miyoshi and Saito [15] found the characteristics of the grinding wheel surface by power spectrum pattern. An ideal grating on the aluminium disc was produced with a number of equidistant strips sculptured on it parallel to the axis of the disc having certain width and distance between them. He-Ne laser was used as light source. Using a lens system as shown in the figure (4) average power spectrum is obtained by rotating the grinding wheel. It was seen that the point where the power spectrum pattern falls to zero value corresponds to the average width of reflection surface and the second maxima in the pattern corresponds to the gap between reflection surface. Assuming each reflection surface to be an average width of wear flats, width of wear flats and gap between the wear flats is measured on the grinding wheel. They drew a graph between number of strokes and width of wear flats and proposed to dress the wheel after certain number of strokes when the width of wear flats drops again.

Fig. (2a) shows the power spectrum for double slit with ideal grating depth (d) and width (b) ratio of 3.

The power spectrum has several maxima except for principal maxima in the centre which corresponds to the point representing infinite wave length i.e. direct current.

The dotted curve falls to zero at $X = \lambda f/b$ and the intensity is considered to be nearly zero for $X \leq \lambda f/b$, where b is the width of slit. So the width of slit (b) can be estimated by measuring the points where the spectrum falls to zero value.

Fig. (2b) shows the power spectrum pattern obtained from the ideal grating on the aluminium disc having grating dimensions d/b = 3.16. The wave length u is reciprocals of spatial frequency .

$$\mu = \frac{K\ X}{\lambda\ f}$$

where $K = \frac{f_o}{R}$, f_o = focal length of cylindrical lens CL.

R = radius of grinding wheel.

λ = wave length of laser light

f = focal length of lens L_3

the spectrum obtained from the disc is similar to ideal grating shown in Fig. (2a). So the wave length $u_o = \frac{\lambda\ f}{K\ X_o}$ where the power spectrum falls to 0 corresponds to width of grating made in the disc.

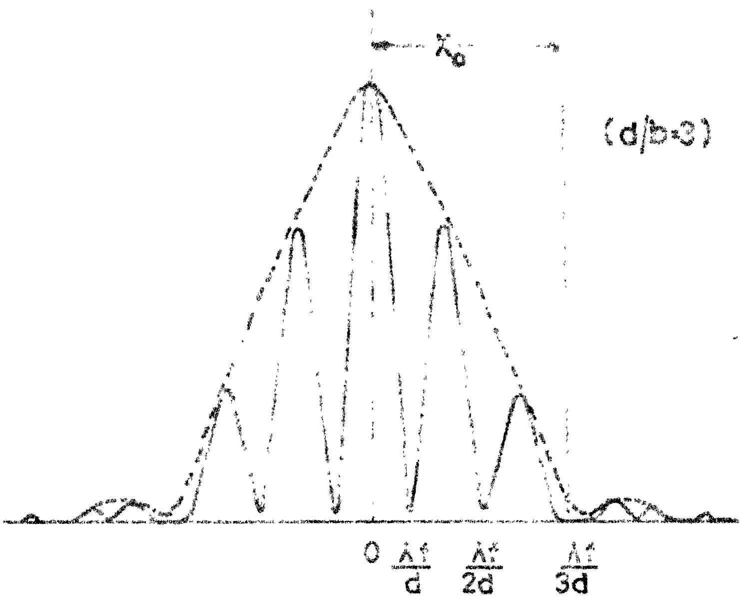

FIG-2a POWER SPECTRUM OF IDEAL GRATING FOR DOUBLE SLIT

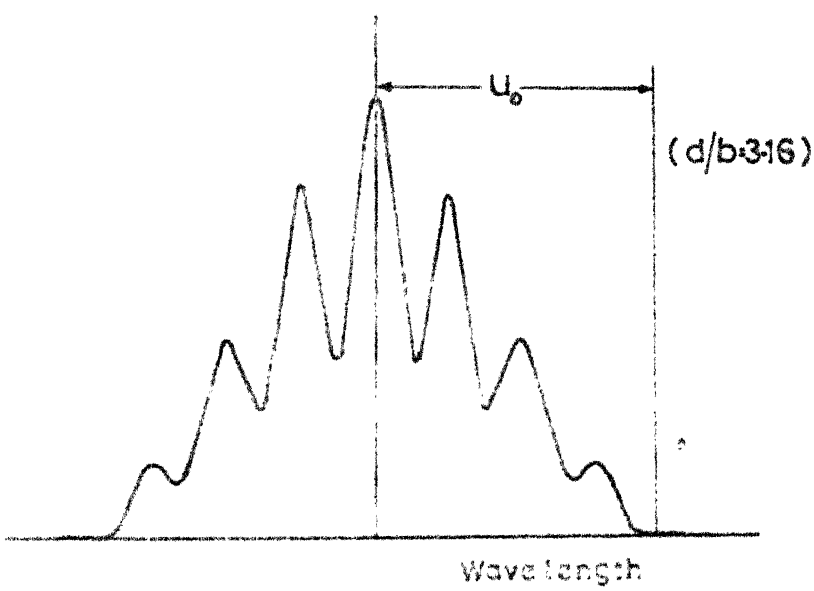

FIG-2b POWER SPECTRUM PATTERN OF GRATING ON WHEEL SURFACE

S. Malkin [16] investigated burning limit for surface and cylindrical grinding of steels. It was proposed that burning threshold corresponds to reaching a critical grinding zone temperature. A expression for energy input at the onset of burning in terms of grinding parameters was established. Experiments showed that tangential and normal grinding forces increase linearly with wear flat area.

Chaudhary [17] studied in-process monitoring of random vibration signal during surface grinding and discussed the effect of wheel loading and wheel wear on the power spectral density. It was concluded that, because of excessive loading and wheel wear, power spectral density suddenly increases after specified number of passes.

1.3 PRESENT WORK:

Review of literature survey shows that there is a need to explore the possibility of applying spectral analysis to adaptive control of grinding process. The objective of present work is in-process assessment of dressing condition by (i) applying random analysis and (ii) measuring width of wear flats and the intensity of light reflected from the wheel during surface grinding operation.

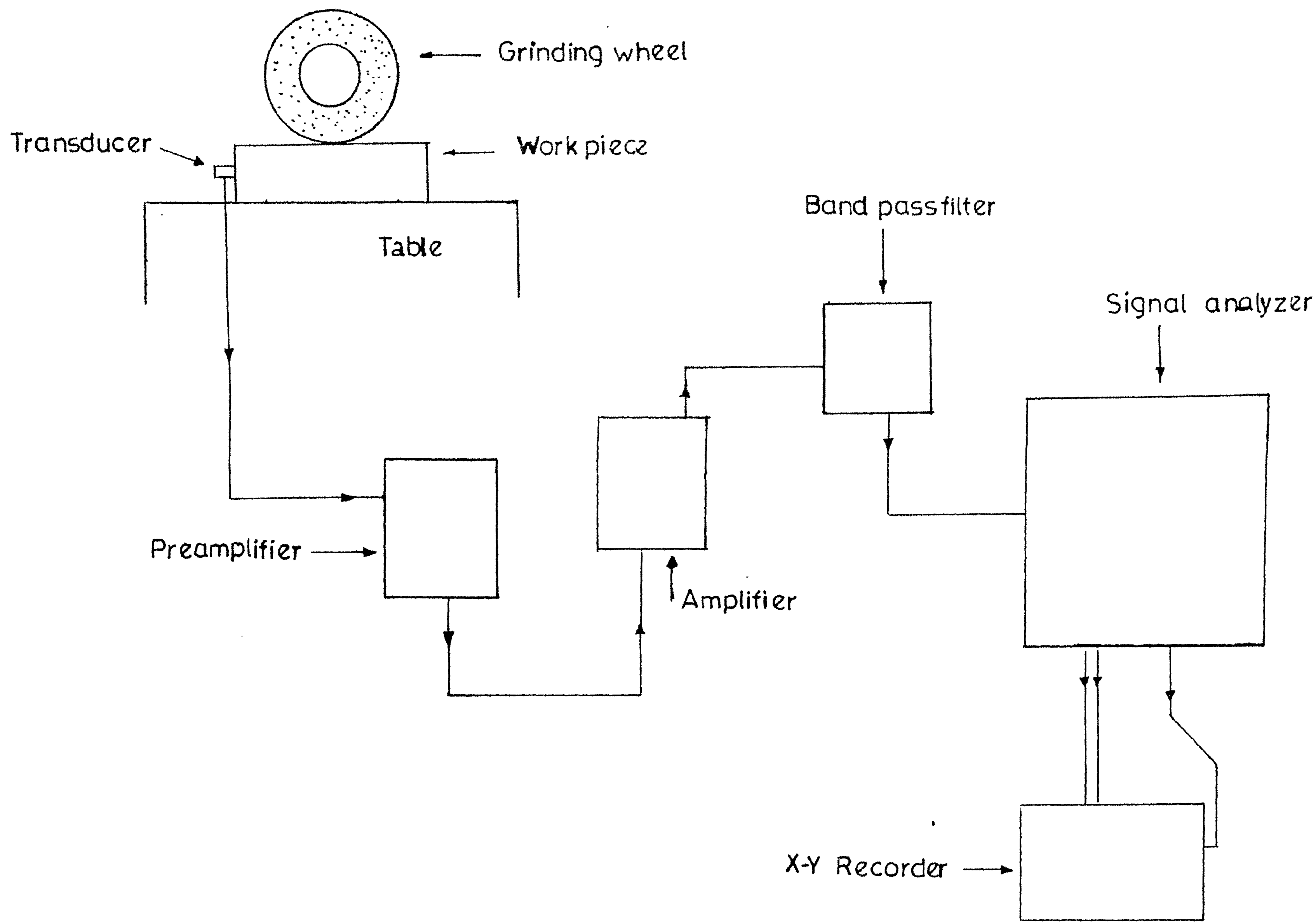

FIG. 3 TEST SETUP FOR VIBRATION SIGNAL RECORDING

CHAPTER-2

EXPERIMENTAL DETAILS

2.1 INTRODUCTION:

Experiments are carried out for in-process assessment of dressing condition of grinding wheel under plunge cut conditions on a horizontal surface grinding machine. Tangential vibrations are analysed for power spectral density function. Topography of the grinding wheel is found by power spectrum pattern of laser beam reflected from the surface of the grinding wheel.

2.2 EXPERIMENTAL SET UP:

2.21 Signal Recording:

The schematic diagram of the test set up for recording the vibration signal is shown in Fig. 3. Tangential vibrations are measured during surface grinding. Piezoelectric type of transducer (B.K. accelerometer type 4334) is used to monitor the vibration signal.

The transducer is suitably mounted with the help of magnetic base on the test piece to sense the vibration in the tangential direction. The signal is

amplified by a preamplifier(B-K preamplifier type 1606) and two stage amplifier (B-K microphone amplifier type 2603). The amplified signal is passed through a band pass filter (K-H Model 3700) having a frequency range of 0.2 Hz to 20,000 Hz. The lower cut off frequency is chosen so as to filter the noise from the various sources in the system. The higher cut off frequency is chosen as 6.5 KHz. Lower and higher cut off frequencies are decided on the basis of preliminary grinding tests and the natural frequency of machine tool. Finally the output signal is fed to the input channel of the signal analyzer.

Vibration signals, produced during the operation, are in analog form. To record these signals, the signal analyzer (SM-2100) is used. Signal analyzer has analog to digital conversion system, having sequential comparison system, with conversion time within 2.4 μs. Input to the analyzer is given to one of its channels. Volts full scale is chosen depending upon the maximum voltage in the signal. This scale represents the analog to digital conversion range. System is brought to 'sum average mode' to execute summation averaging operation. This is done in order to reduce the effect of the noise of signal. Frequency range 10.0 KHz and data length 2K are selected to fix the time for which the

signal is to be recorded. The system is brought to auto mode and hanning window is chosen to smoothen the signal in order to eliminate all the unwanted irregularities. Spectral density unit system is chosen. This is the unit of system of random signal, that the spectrum concentrates at frequency by the cursor movement and gives the effective value at the point in terms of voltage^2/Hz. Signal received from the machine are stored in the blocks available and are analysed for power spectral density function.

b. Topography of the Grinding Wheel:

Experimental set up for determination of topography of the wheel is shown in Fig. (4). He - Ne laser (1.5 mW) is used as a light source with wave length of 632.8 nm. The laser beam is collimated with the help of two convex lens L-1, L-2. To get the parallel rays, pin hole having a diameter of 6 mm is placed between the two lenses. Parallel rays are turned through 90° with the help of a plane mirror-M. A half mirror HM is placed which divides the light equally, half the light is transmitted through while the other half is reflected. The transmitted light is then passed through a cylindrical lens-CL to convert plane waves into cylindrical waves. Rays finally fall on the rotating grinding wheel and

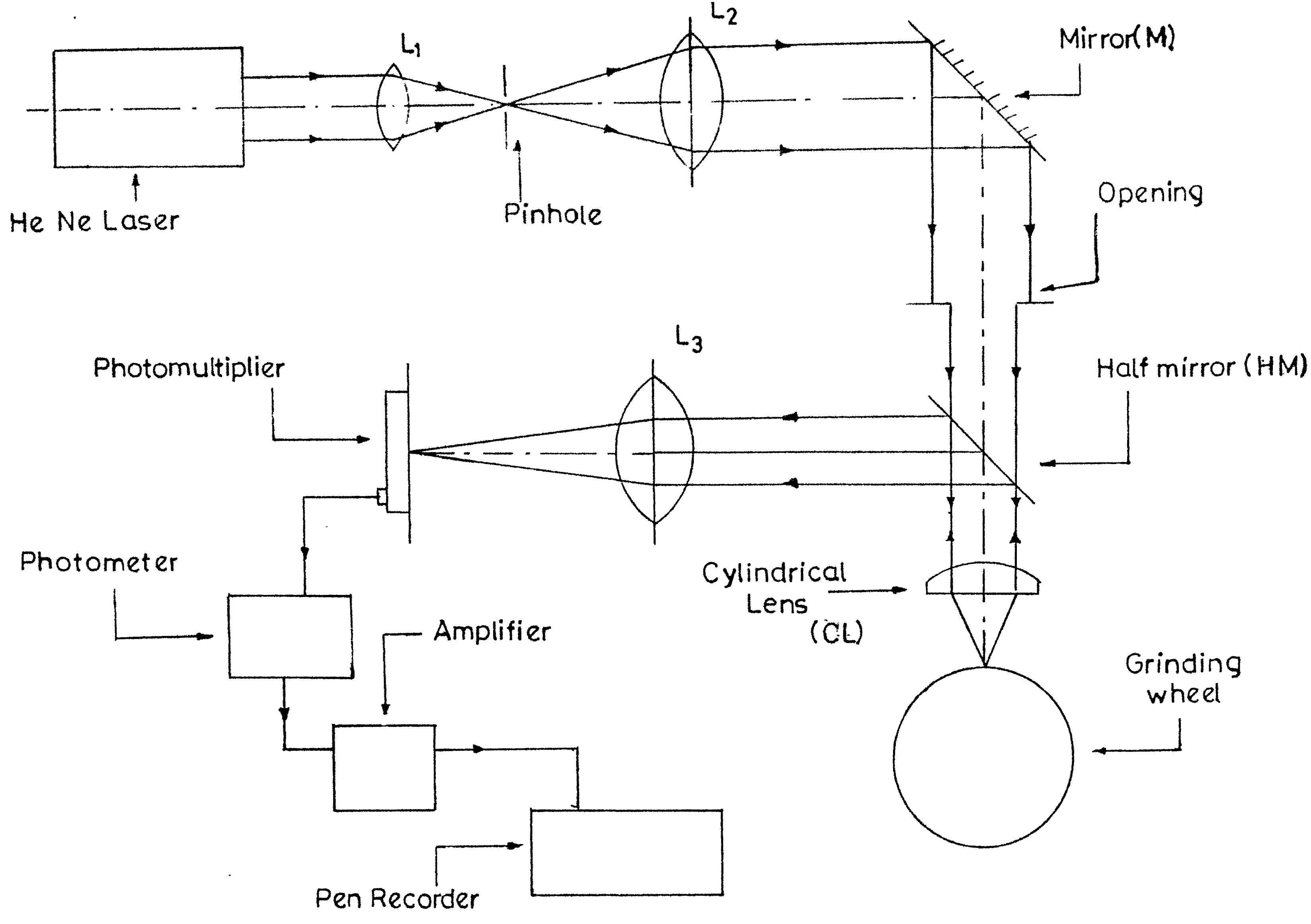

FIG. 4 TEST SETUP FOR POWER SPECTRUM PATTERN OF GRINDING WHEEL

are reflected back and are made to fall on a photomultiplier (Model 520-M) which is placed at the focal plane of lens L-3. The photomultiplier converts the light falling on it into electron current. Output of multiplier is given to photometer and finally the signal is recorded in the strip chart recorder by moving the photomultiplier manually

2.3 EXPERIMENTAL CONDITIONS:

Plunge cut grinding tests are carried out on a mild steel specimen. The experiments are conducted on type SFW-1 model No. 1138 horizontal surface grinding machine manufactured by Hindustan Machine Tools Ltd., Bangalore.

The grinding wheel A 46-J5-V10, supplied by M/s Carborundum Universal Ltd., Madras is used. The diameter, width and bore of the wheel are 264 mm, 63 mm, 76 mm respectively.

The following experimental conditions were employed in the present work.

Wheel speed (V)	1500 rpm
Depth of cut (D)	2,4,6,8,10 microns
Table speed (V)	20 meters/minute
Workpiece material	Mild steel
Length of stroke	500 mm
Grinding fluid	Dry

2.31 Dressing Condition:

Dressing conditions affect the performance of a grinding wheel [10]. In order to obtain reproducible results wheel dressing technique is standardised in terms of down feed and cross feed rate of wheel. Wheel used is subjected to following truing and dressing conditions:-

(1) All traces of loaded material and irregularities of previous grinding operation are removed by truing at a depth of cut of 10 microns during each pass. Truing operation is terminated after giving 5 passes.

(2) Dressing operation is performed with a single point diamond dresser by giving a single pass of 6 microns dressing depth of cut at a cross feed of 2 m/minute.

2.4 PROCEDURE:

The grinding wheel is brought close to the workpiece. The table speed is set at the desired value and the wheel is started. After each stroke the desired depth of cut in up-grinding is given. After specific number of passes, vibration signal is recorded in the signal analyzer. Grinding wheel is removed from the machine and is placed on the roll stand. The topography

of the wheel is found by using power spectrum pattern of the reflected light from the wheel surface.

Power spectral density and topography of the wheel are determined at specific member of passes for different depth of cut of 2,4,6,8 and 10 μm. The range of number of passes is chosen so that sufficient points are obtained before the burn-off condition is reached.

CHAPTER-3

RESULTS AND DISCUSSION

3.1 RESULTS:

3.11 Random Vibration Analysis:-

Various records obtained in random vibration analysis of surface grinding operation, and power spectrum pattern obtained from the surface of grinding wheel by using laser beam are discussed.

Figures 5 to 7 show typical vibration and power spectral density records after 40, 80, 160 passes for 2 microns depth of cut.

Figures 8 to 10 show the typical vibration and power spectral density records after 25, 75 and 125 passes for 6 microns depth of cut. Fig. 11 to 13 show typical vibration and power spectral density records after 15, 45, 75 passes for 10 microns depth of cut.

3.12 Topography of the Wheel:-

Figure 14 and 15 show the typical power spectrum patterns, achieved after specific number of passes for depth of cut 2 microns and 8 microns respectively.

3.2 DISCUSSION:

Figures 16 to 20 (as obtained from the experimental results shown in the Fig. 5 to 15) show the variation of peak power spectral density and wear flat width with number of passes for various depth of cut. The frequencies at which peak PSD occur are also indicated in the graphs. The condition of burn-off, observed from the discolouring of the workpiece, is also indicated in the graphs. Plots show that there is a distinct rise in the power spectral density in each case, before the number of passes where the burn-off is seen on the workpiece. It is also seen that after the number of passes where the burn-off is observed, width of wear flat shows a drop in all the cases. This may be due to the fact that after initial burn-off the load on abrasive grain becomes high due to increased width of flats and further grinding results in removal of flattened grains thereby, presenting new cutting edges resulting in smaller average width of flat.

Fig. 21 shows the intensity of power spectrum pattern, from figures similar to Fig. 14, 15 are plotted v/s number of passes for various depth of cut. It is clearly seen that the intensity increases with number of passes upto burn-off and shows a steep fall immediately

after the condition of dressing is reached due to the reason explained in the last paragraph. Furthermore, it is interesting to note that the intensity at burn-off does not change appreciably (range 45 to 48 mV) with an average value of approximately 47 mV. As the intensity at burn-off is independent of depth of cut, it can be used for in-process monitoring the condition of the grinding wheel for the purpose of adaptive control.

Fig. 22 shows the variation of peak power spectral density at burn-off and number of passes at burn-off with depth of cut. Plots indicate that depth of cut is related with power spectral density and hence the vibration amplitude at burn-off. It is also seen that number of passes at burn-off decreases with the increase in depth of cut.

It is generally desirable that the grinding operation should be interrupted before condition of burn-off are approached for specific grinding conditions. The steep rise of PSD (Fig. 16 to 20) can be monitored to estimate the condition before burn-off. This could lead to in-process monitoring of the condition of the grinding wheel for subsequent dressing before the burn-off is about to damage the workpiece. There is some correlation which has been observed between position at

which burn-off occurs and the drop in width of wear flat as measured from the power spectrum pattern obtained by a laser beam. Similar results have been reported by [15]. However in order that the technique can be used for automatic control for dressing of grinding wheel, more work needs to be done.

CHAPTER-4

CONCLUSION AND FUTURE WORK

4.1 CONCLUSION:

Review of results obtained shows that while grinding mild steel with A 46-J5-V10 wheel for specific up grinding conditions, there is a steep rise in peak power spectral density before the burn-off is seen on the workpiece for range of depth of cut used in the experiments. There is a significant change in the condition of grinding wheel as indicated by the change in width of wear flats by laser beam spectrum analysis.

The steep rise in the power spectral density can be monitored to estimate the condition before burn-off. There exists a correlation between number of passes and the width of wear flats on the grinding wheel. The intensity of power spectrum at burn-off is independent of depth of cut and it could be used for in-process monitoring of the condition of the grinding wheel for subsequent dressing before the burn-off is about to damage the workpiece.

4.2 FUTURE WORK:

For future work it is suggested that some correlation could be obtained between number of passes at burn-off and depth of cut, with different table speed and different combination of grinding wheel. This would give an indication after how many passes the grinding operation is to be interrupted in order to avoid burning on the workpiece and subsequent poor surface finish.

The laser spectrum analysis could be adopted for in-process monitoring of the condition of the grinding wheel.

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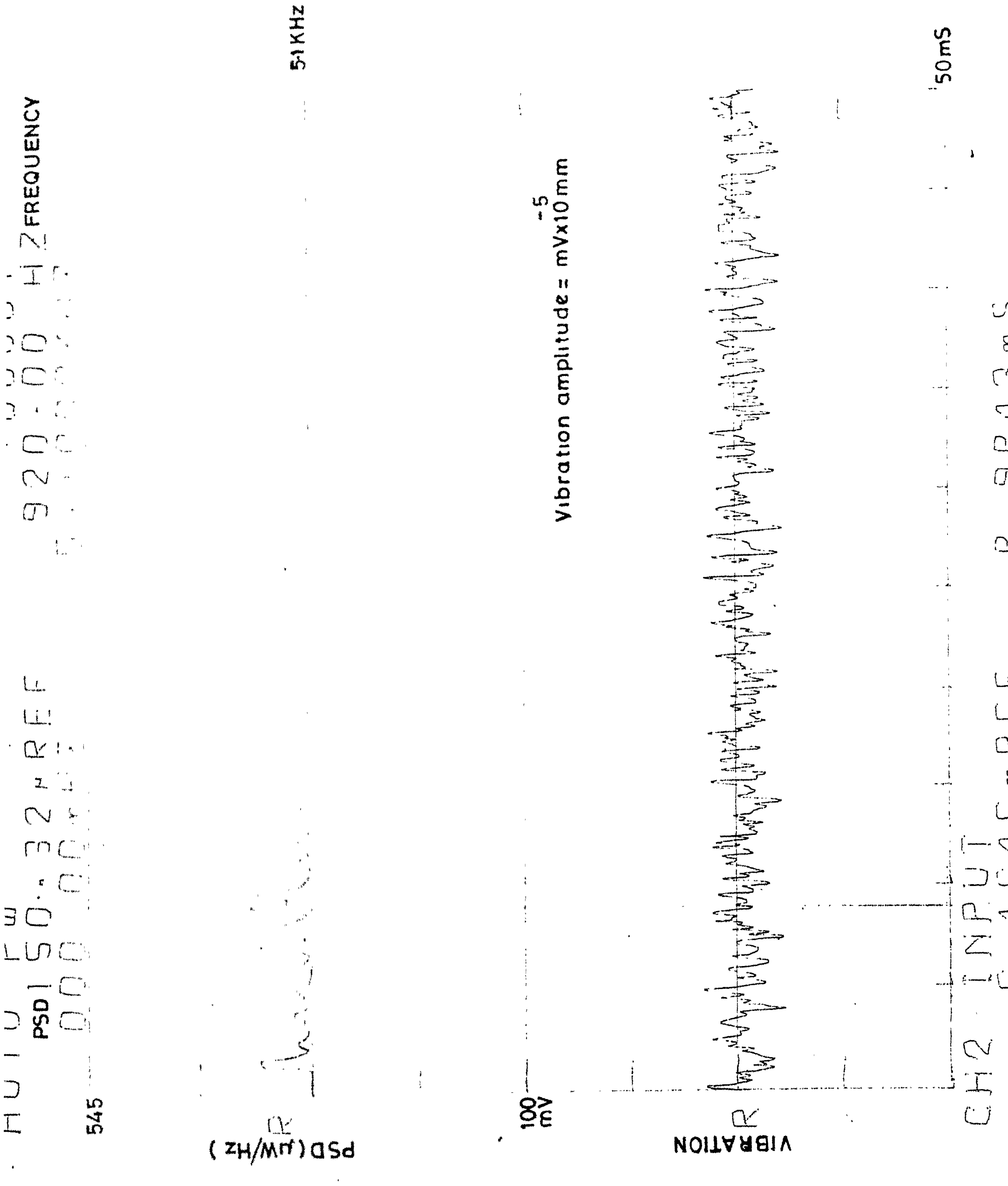


FIG.5 RECORDS OF VIBRATION AND PSD SIGNAL
D=2MICRONS , N=40 PASSES

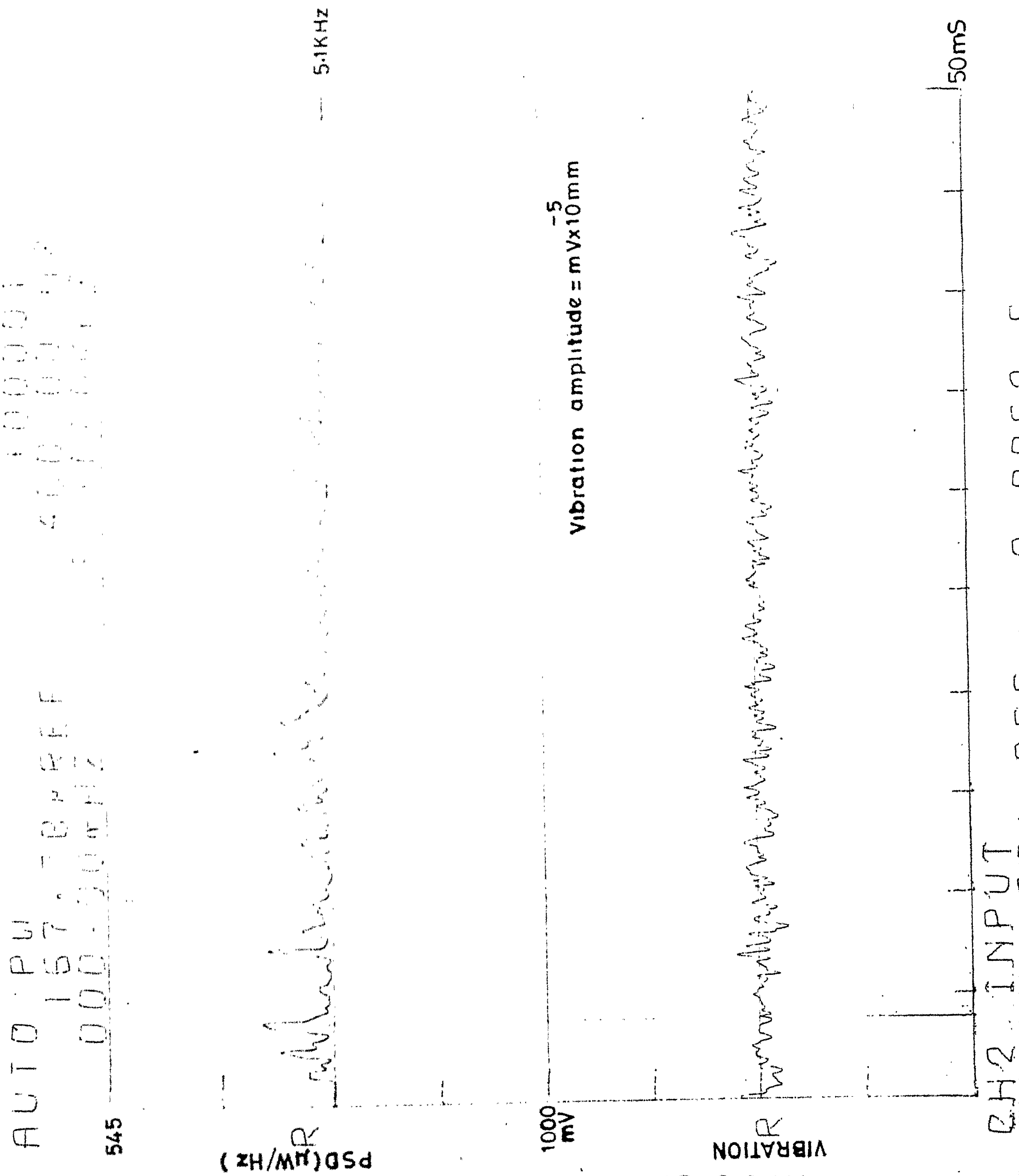


FIG6 RECORDS OF VIBRATION AND PSD SIGNAL
D=2MICRONS , N=80 PASSES

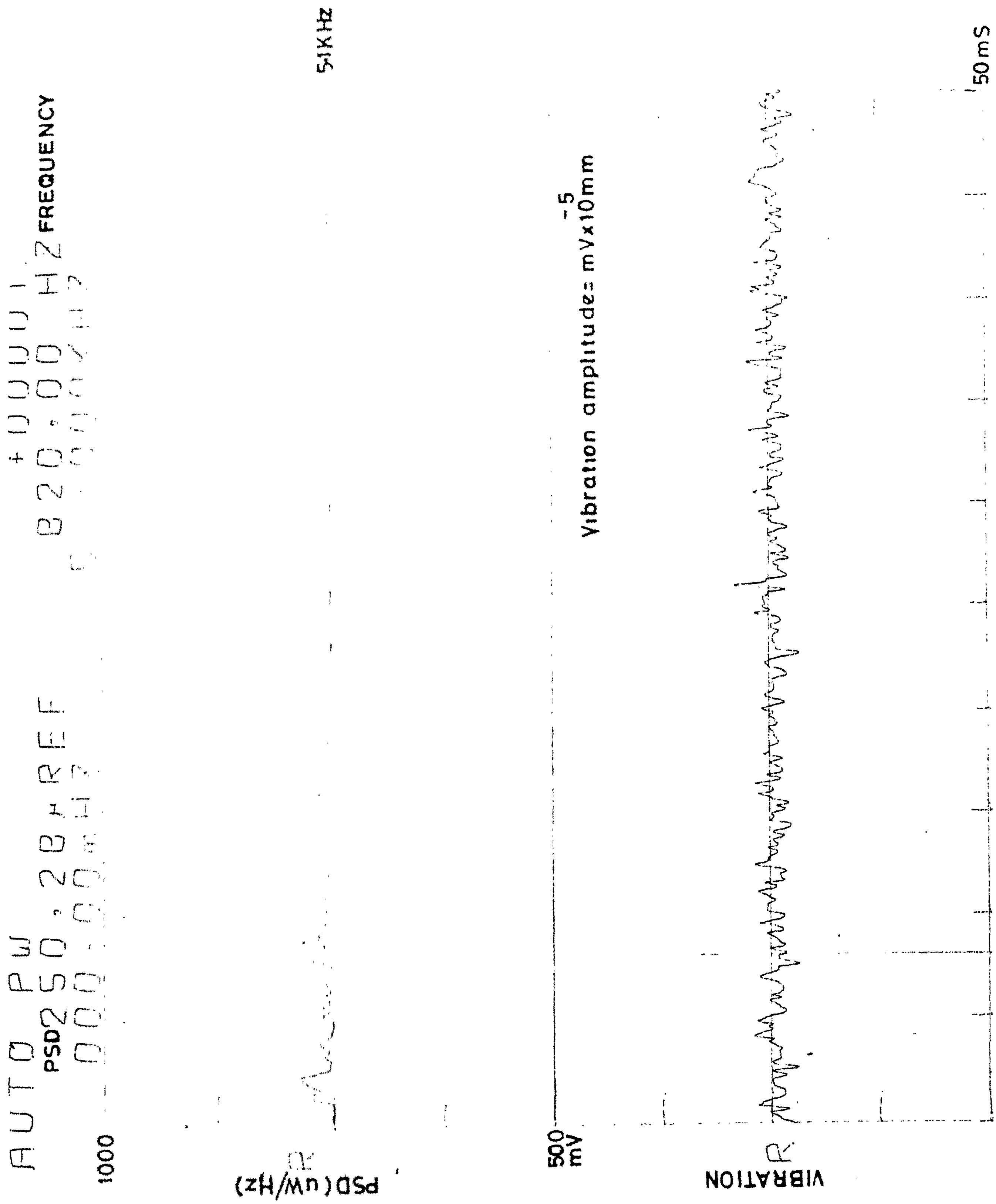


FIG.7 RECORDS OF VIBRATION AND PSD SIGNAL
D=2MICRONS , N=160PASSES

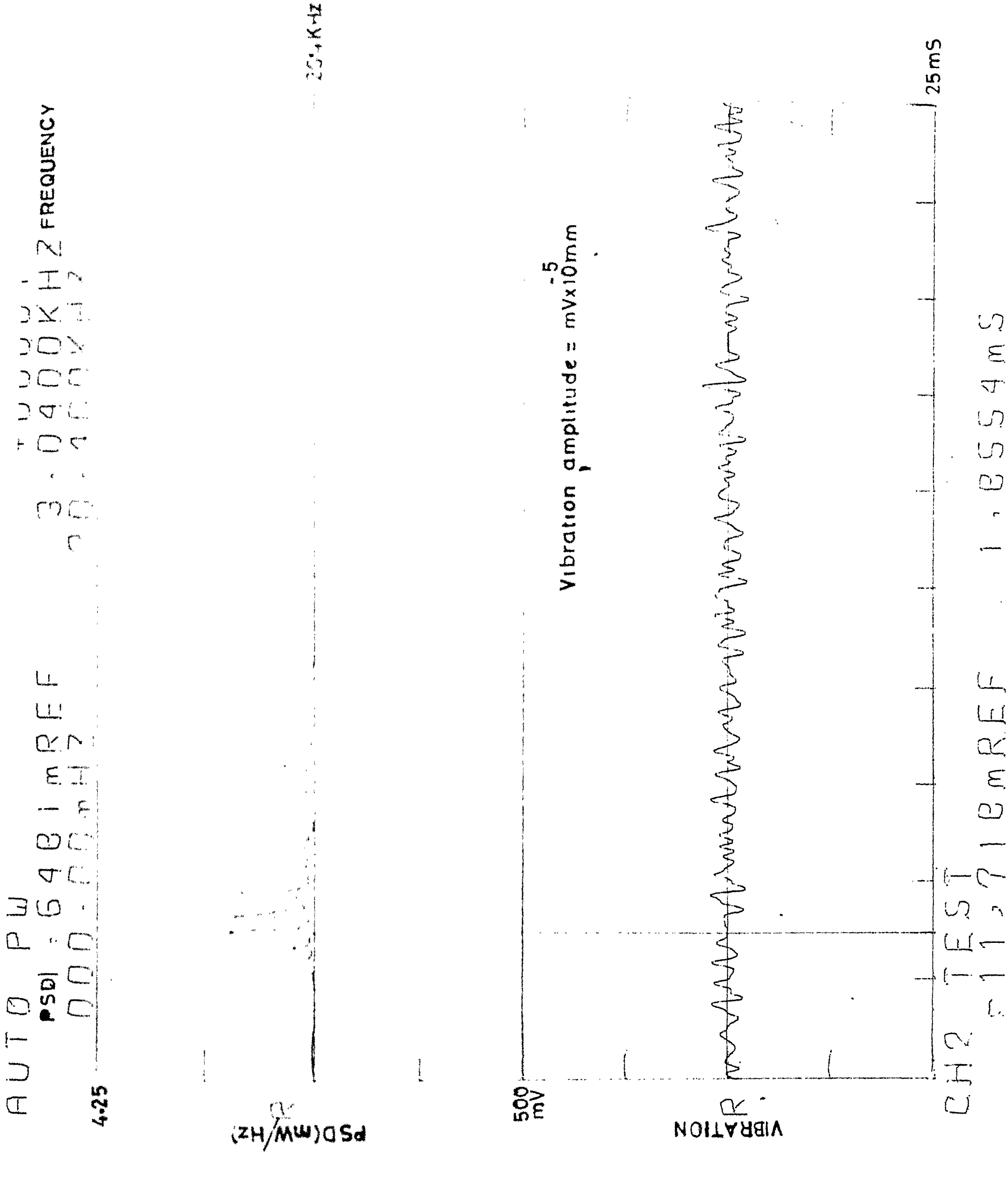


FIG.8 RECORDS OF VIBRATION AND PSD SIGNAL
D=6MICRONS , N=25PASSES

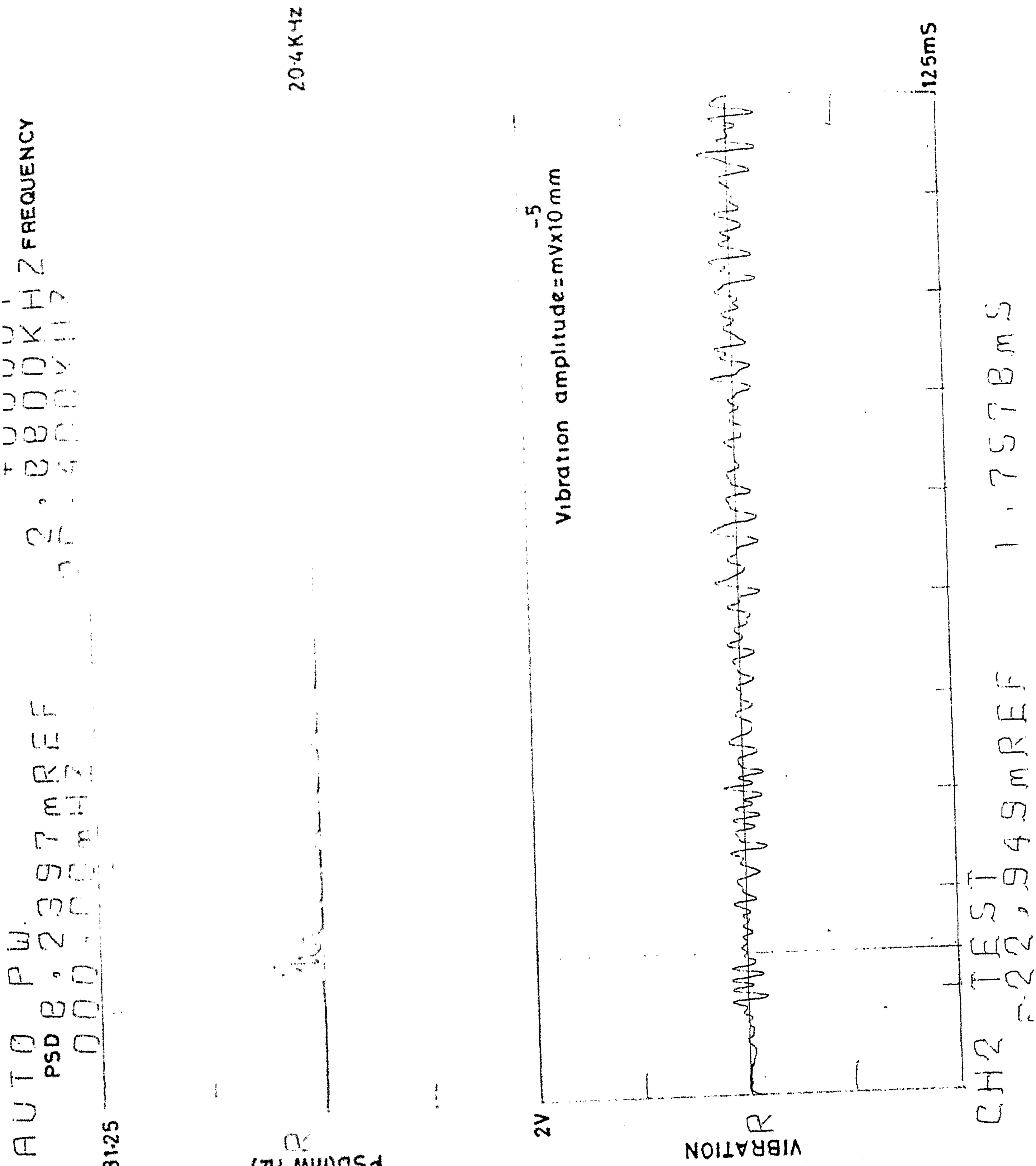


FIG.9 RECORDS OF VIBRATION AND PSD SIGNAL
D=6MICRONS, N=75PASSES

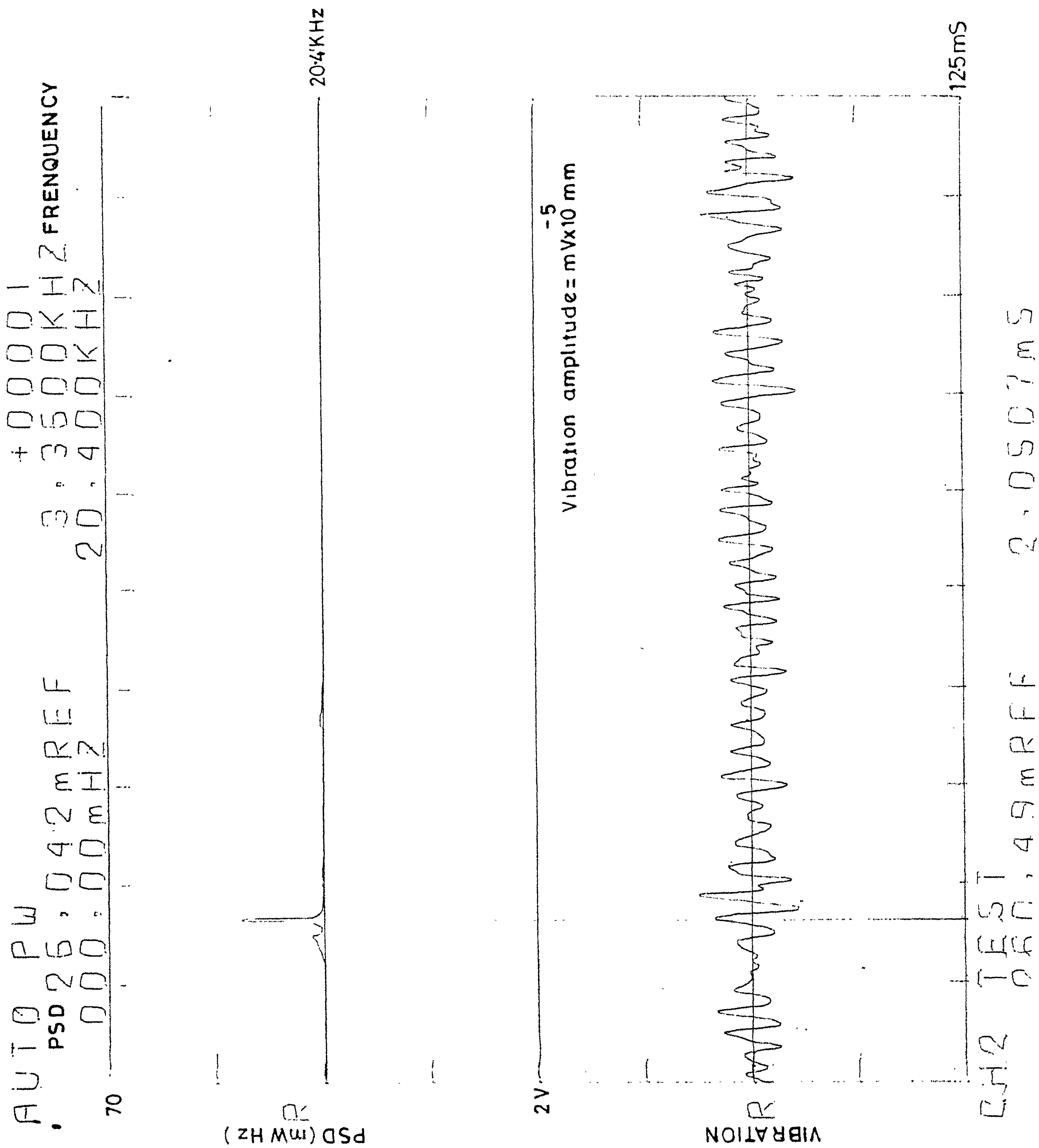


FIG.10 RECORDS OF VIBRATION AND PSD SIGNAL
D=6MICRONS , N=125 PASSES

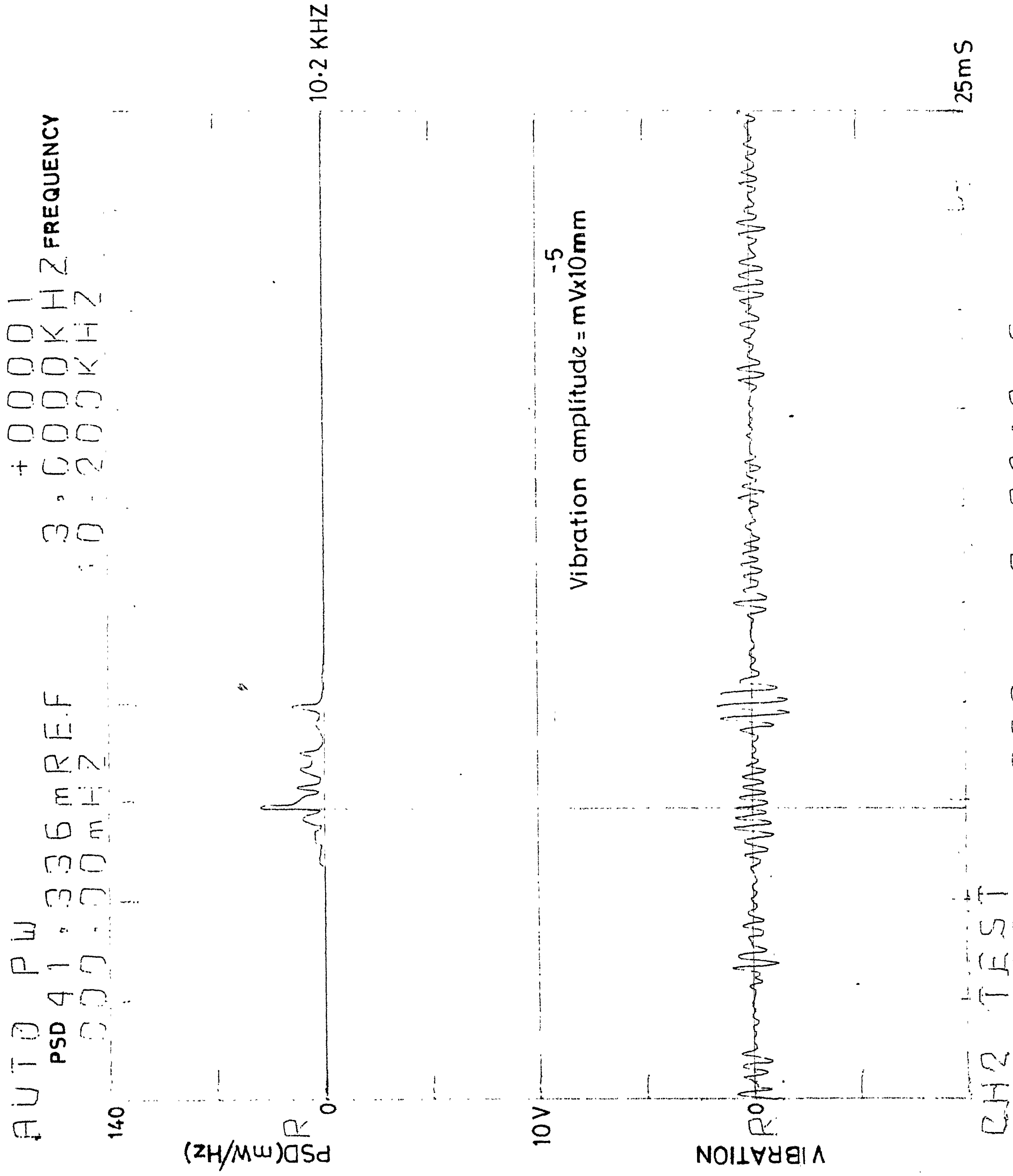


FIG.11 RECORDS OF VIBRATION AND PSD SIGNAL
D=10 MICRONS ; N=15 PASSES

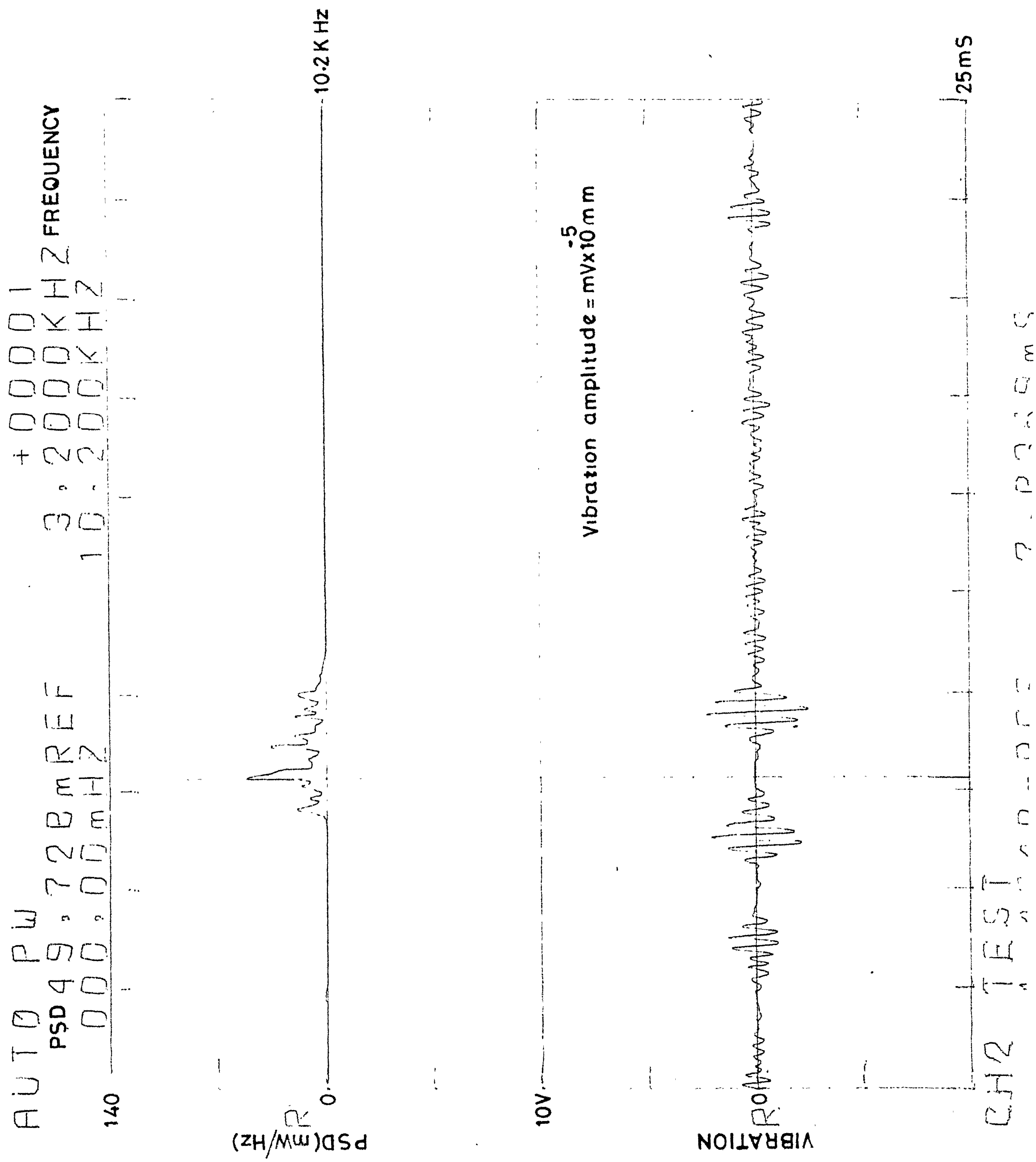


FIG.12RECORDS OF VIBRATION AND PSD SIGNAL
D=10MICRONS , N=30PASSES

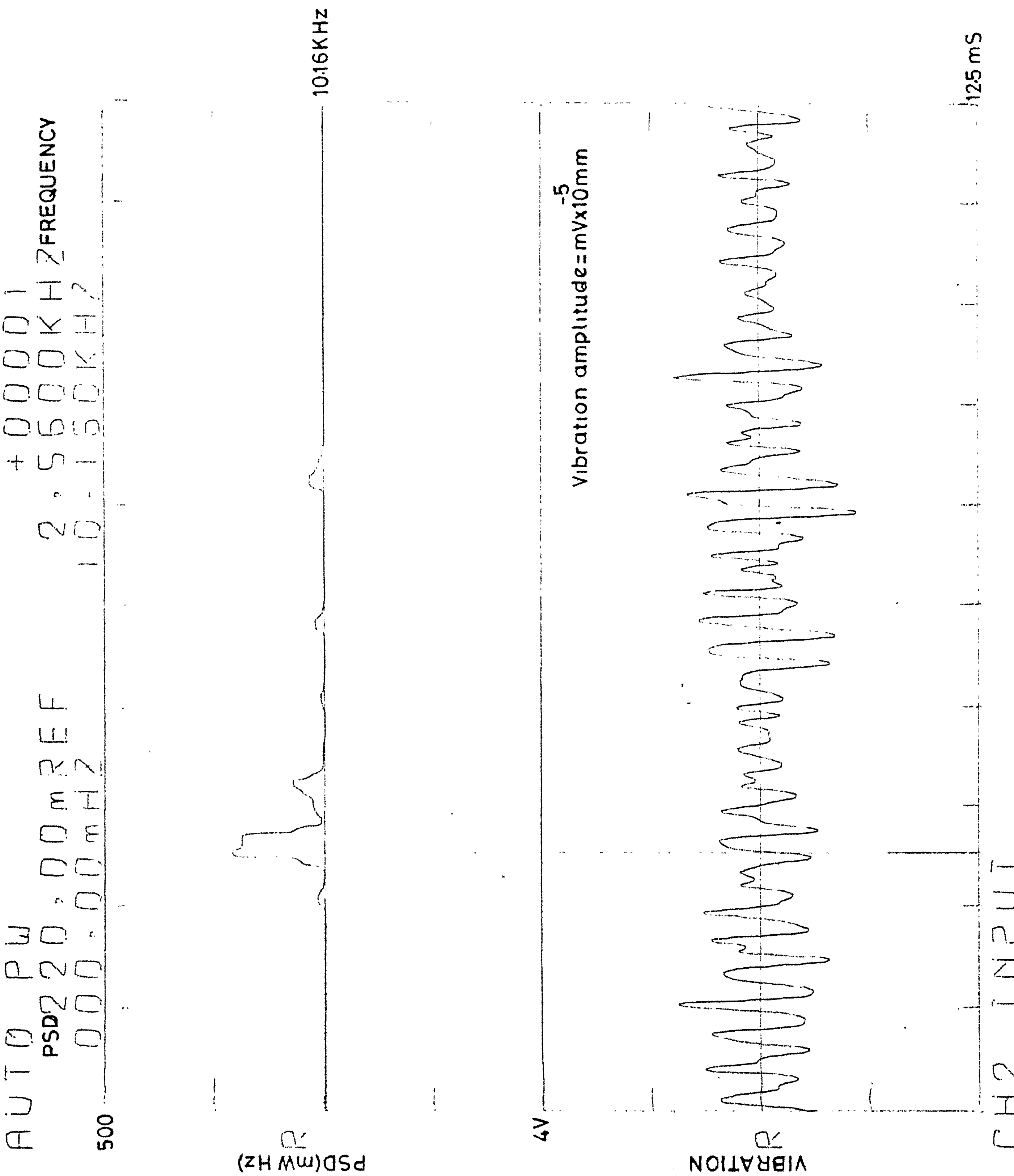


FIG.13 RECORDS OF VIBRATION AND PSD SIGNAL
D=10 MICRONS , N=75 PASSES

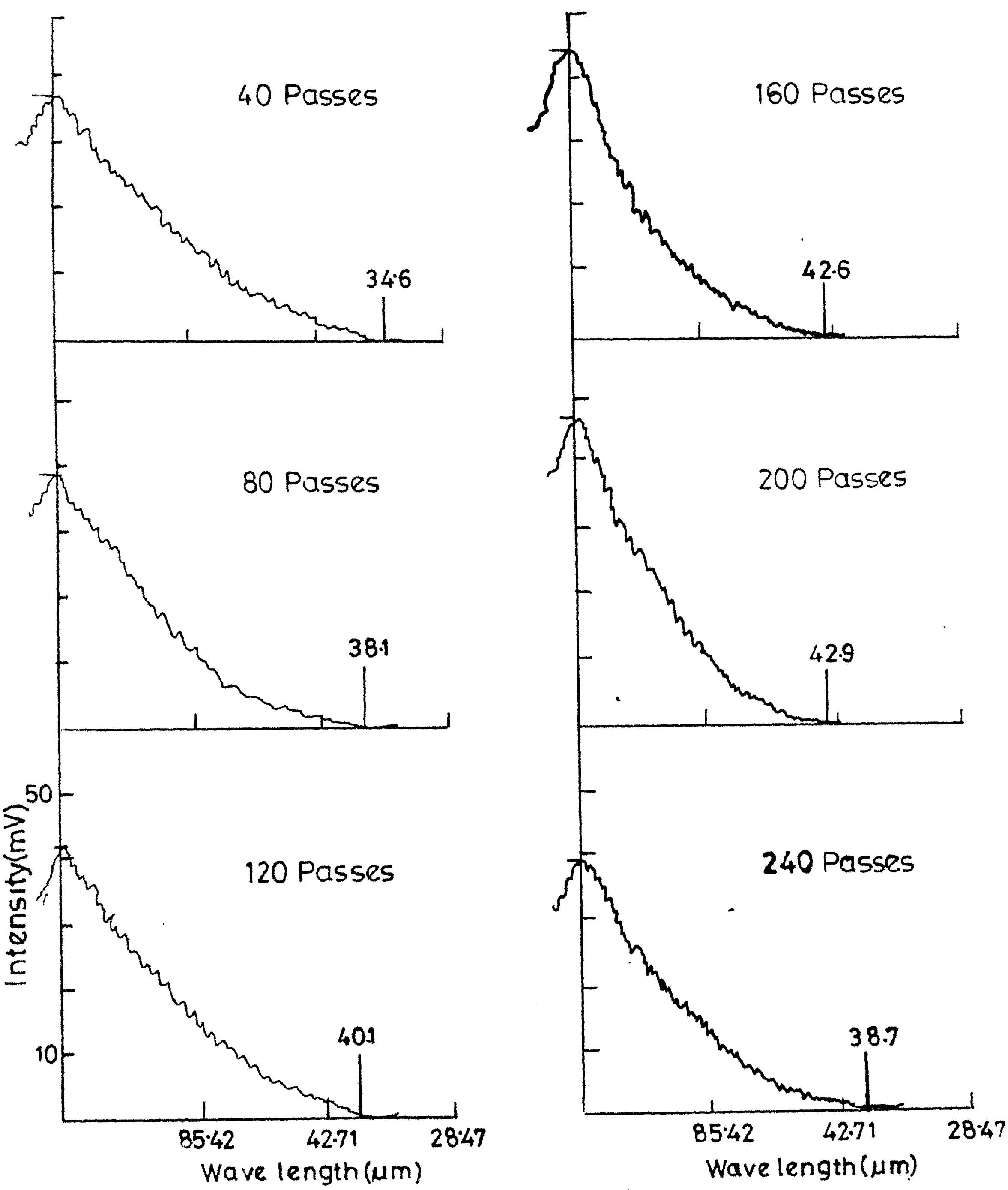


FIG.14 POWER SPECTRUM PATTERN
OBTAINED FROM GRINDING WHEEL
D=2 MICRONS

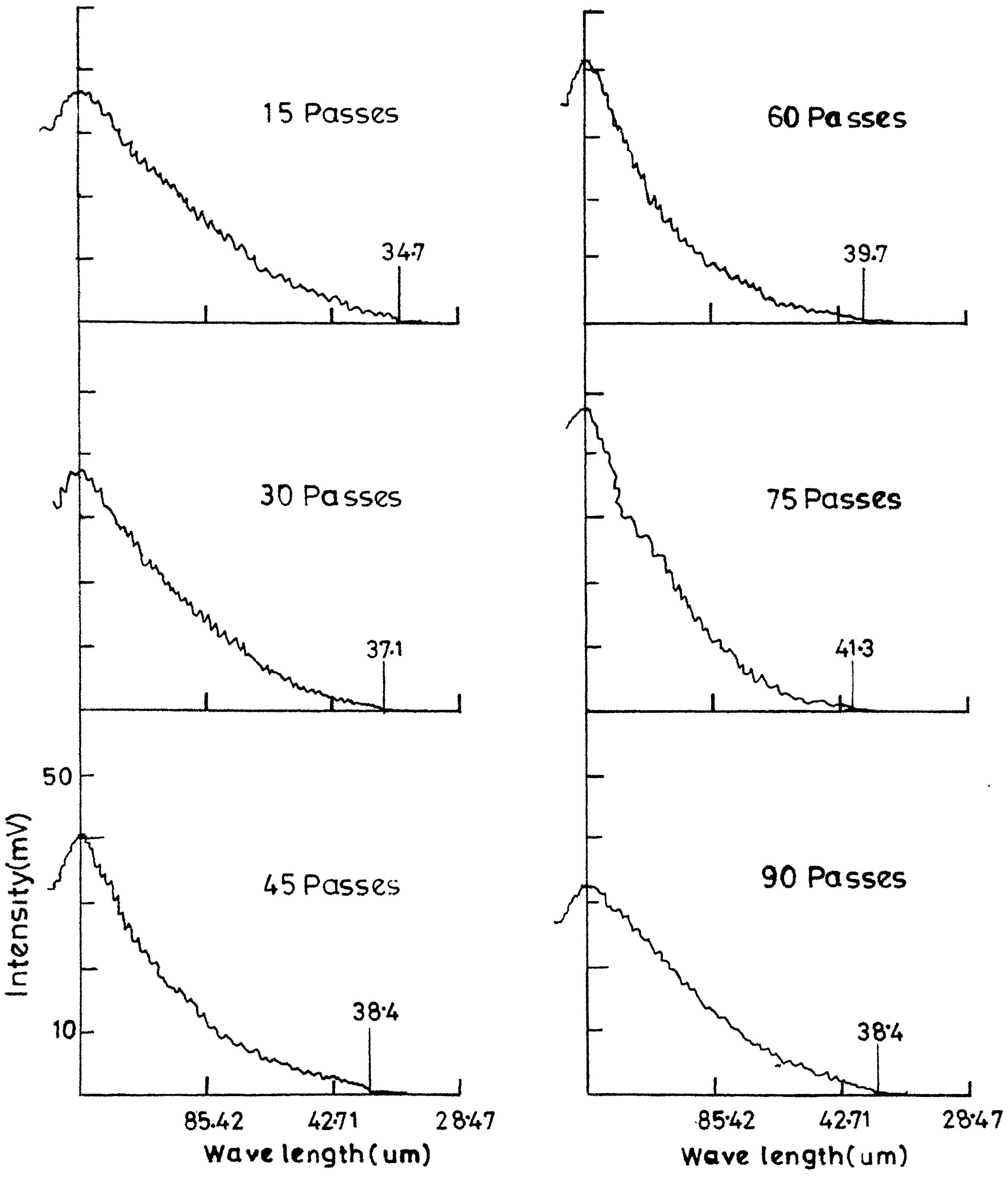


FIG.15 POWER SPECTRUM PATTERN OBTAINED FROM GRINDING WHEEL D=8MICRONS

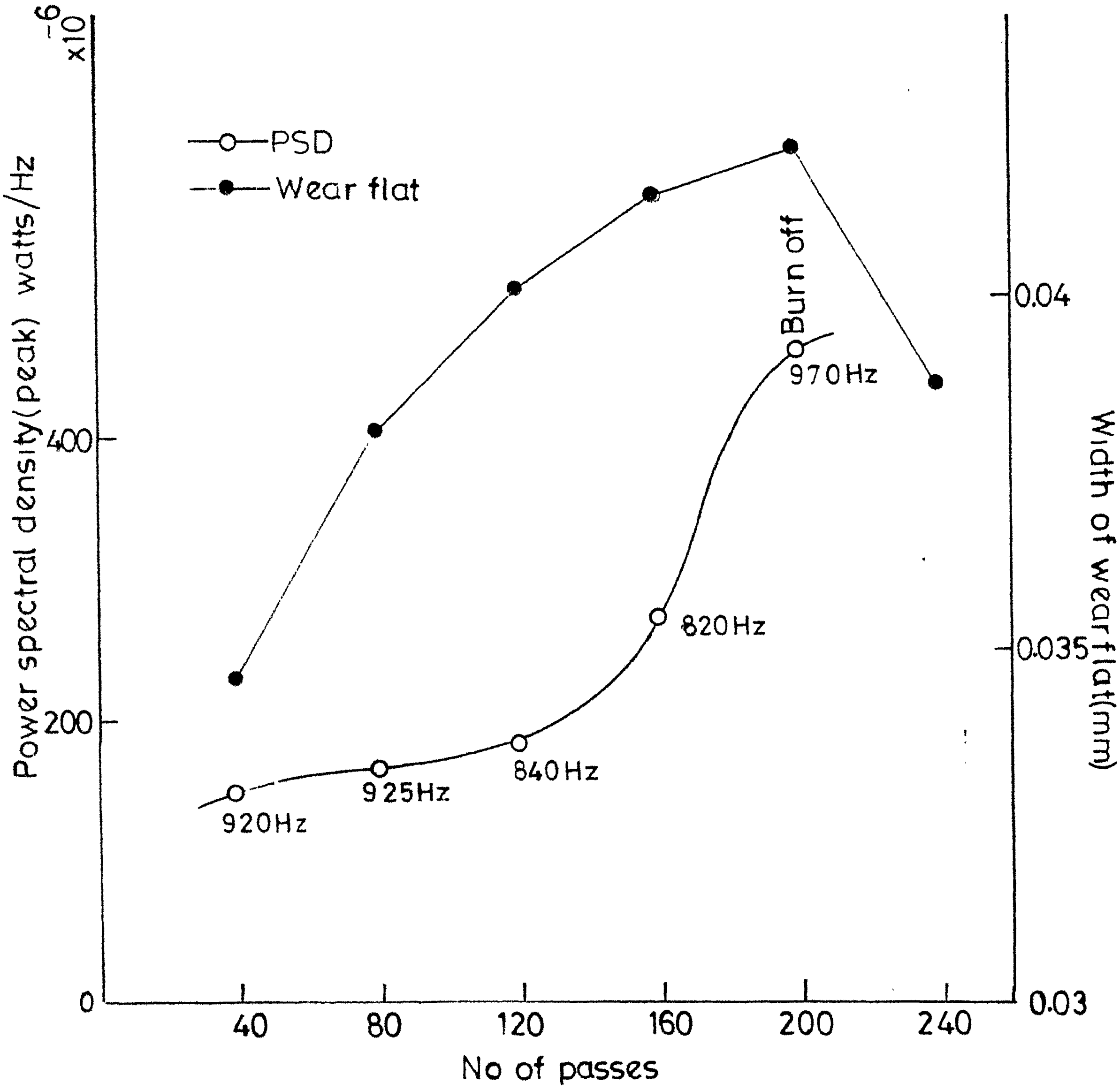


FIG.16 VARIATION OF PSD AND WEAR FLAT WIDTH WITH NO OF PASSES, D=2MICRONS

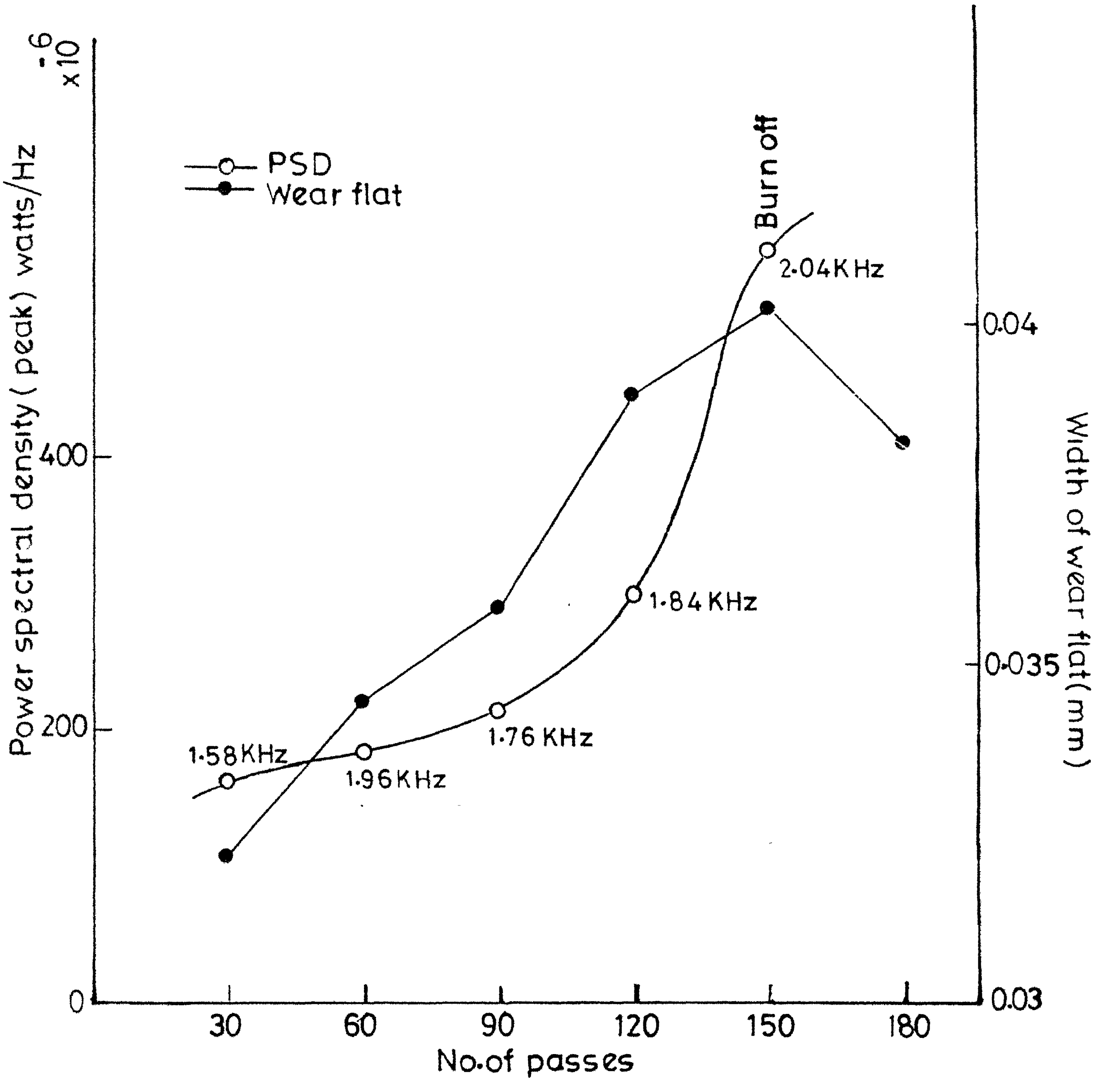


FIG-17 VARIATION OF PSD AND WEAR FLAT WIDTH WITH NO.OF PASSES, D=4MICRONS

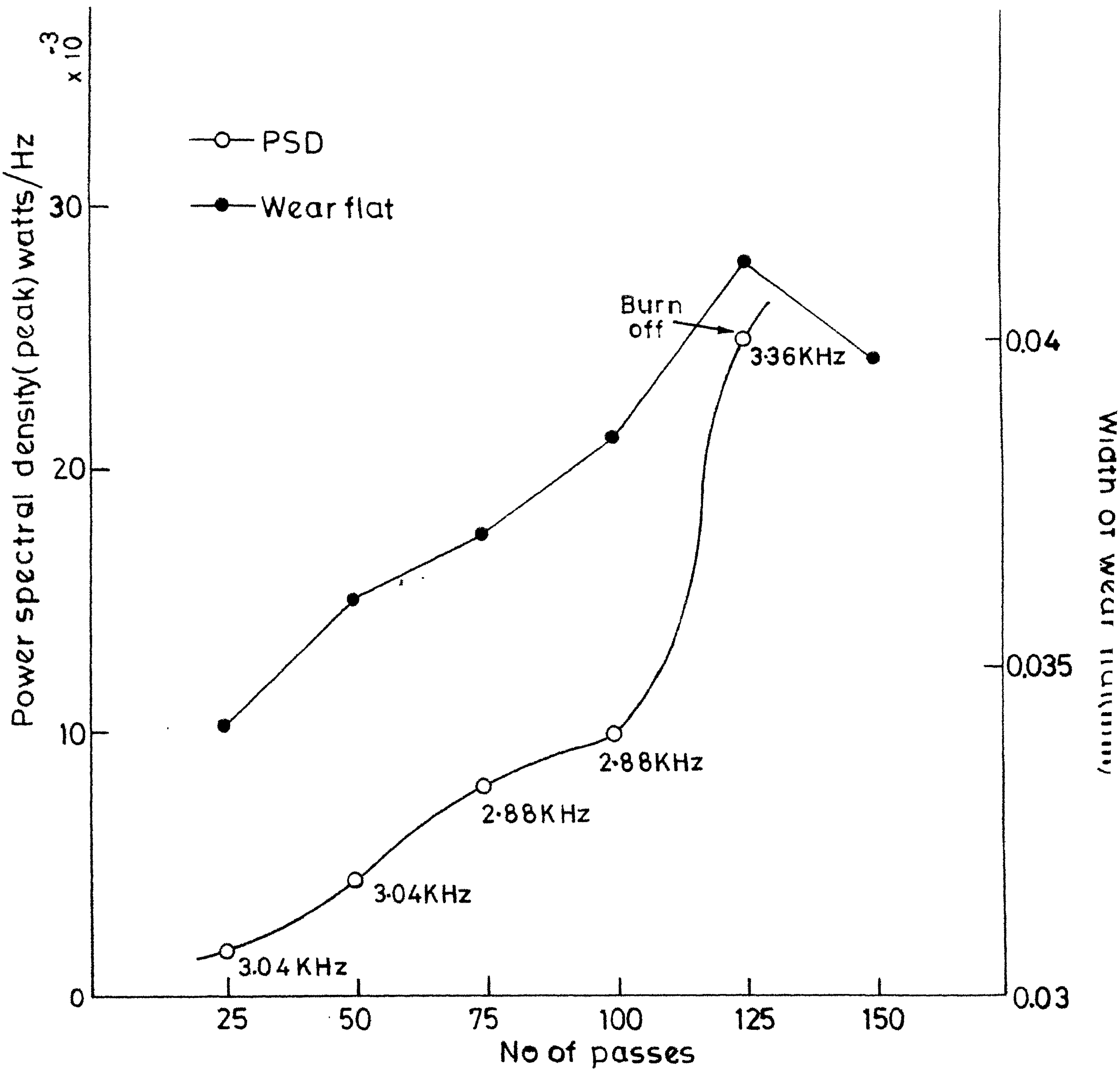


FIG.18 VARIATION OF PSD AND WEAR FLAT WIDTH WITH NO OF PASSES, D=6MICRONS

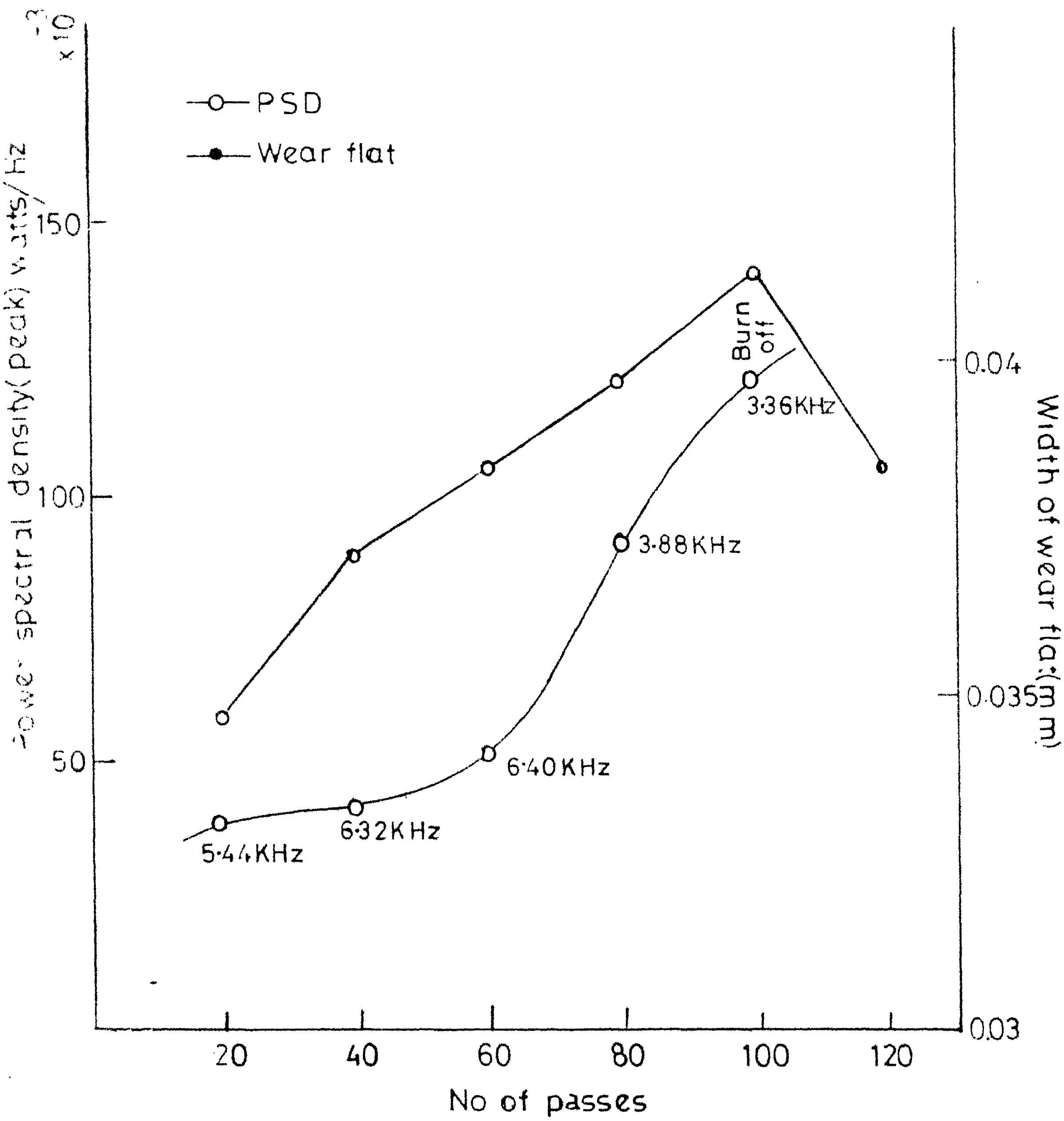
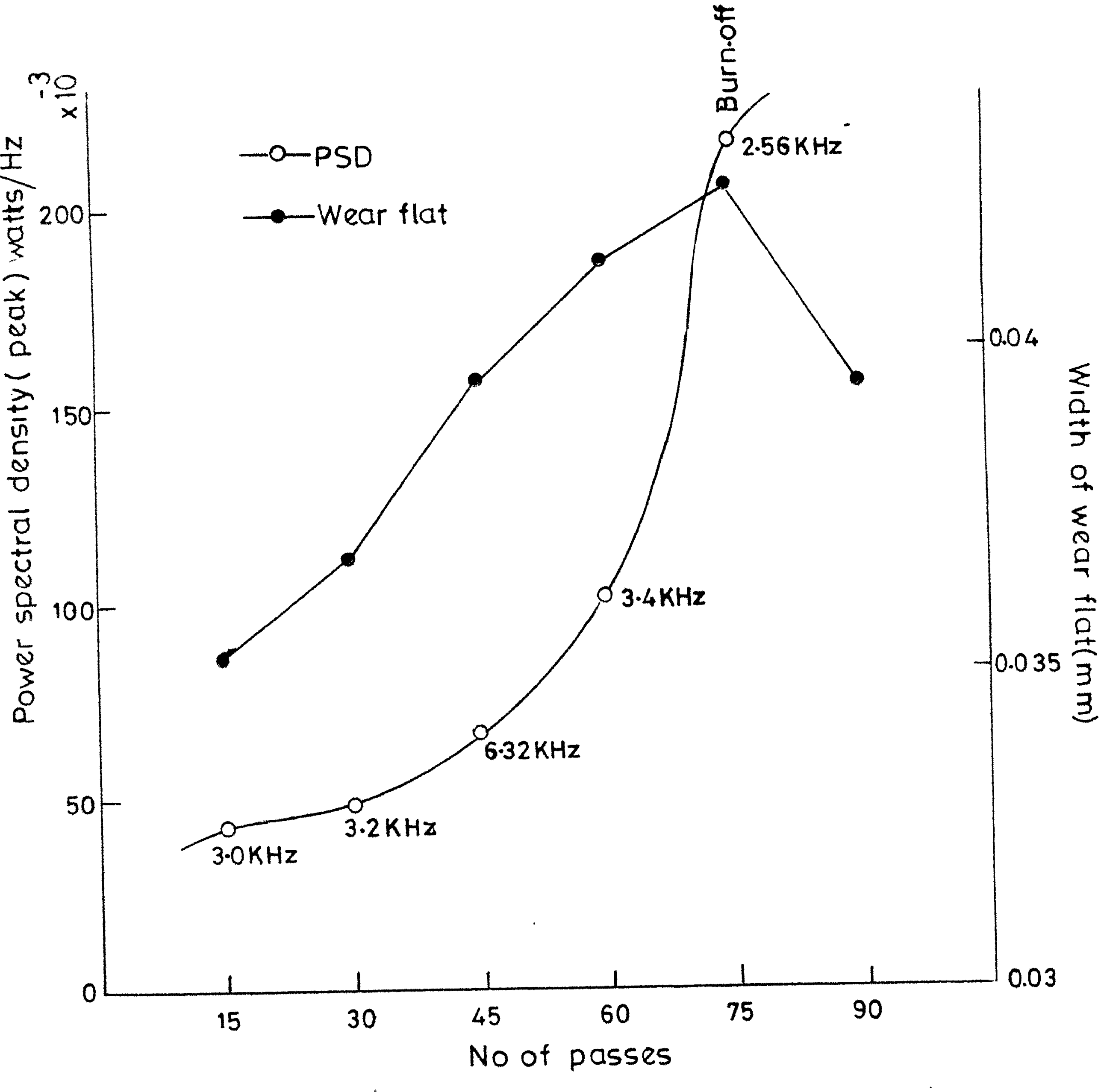
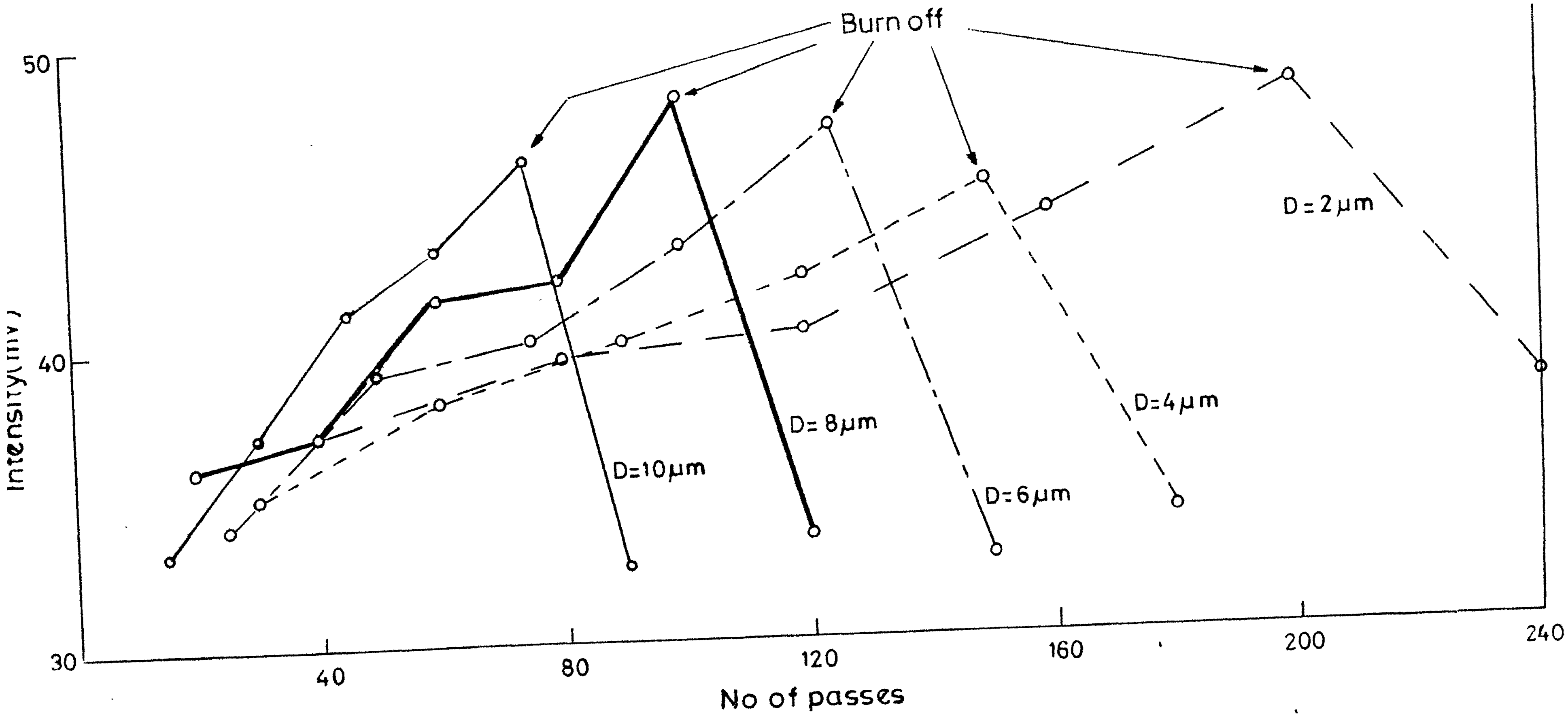


FIG-19 VARIATION OF PSD AND WEAR FLAT WIDTH WITH NO OF PASSES, D=8MICRONS



FIG·20 VARIATION OF PSD AND WEAR FLAT WIDTH WITH NO OF PASSES, D=10 MICRONS



FIG·21 VARIATION OF INTENSITY WITH NO OF PASSES FOR DIFFERENT DEPTH OF CUT

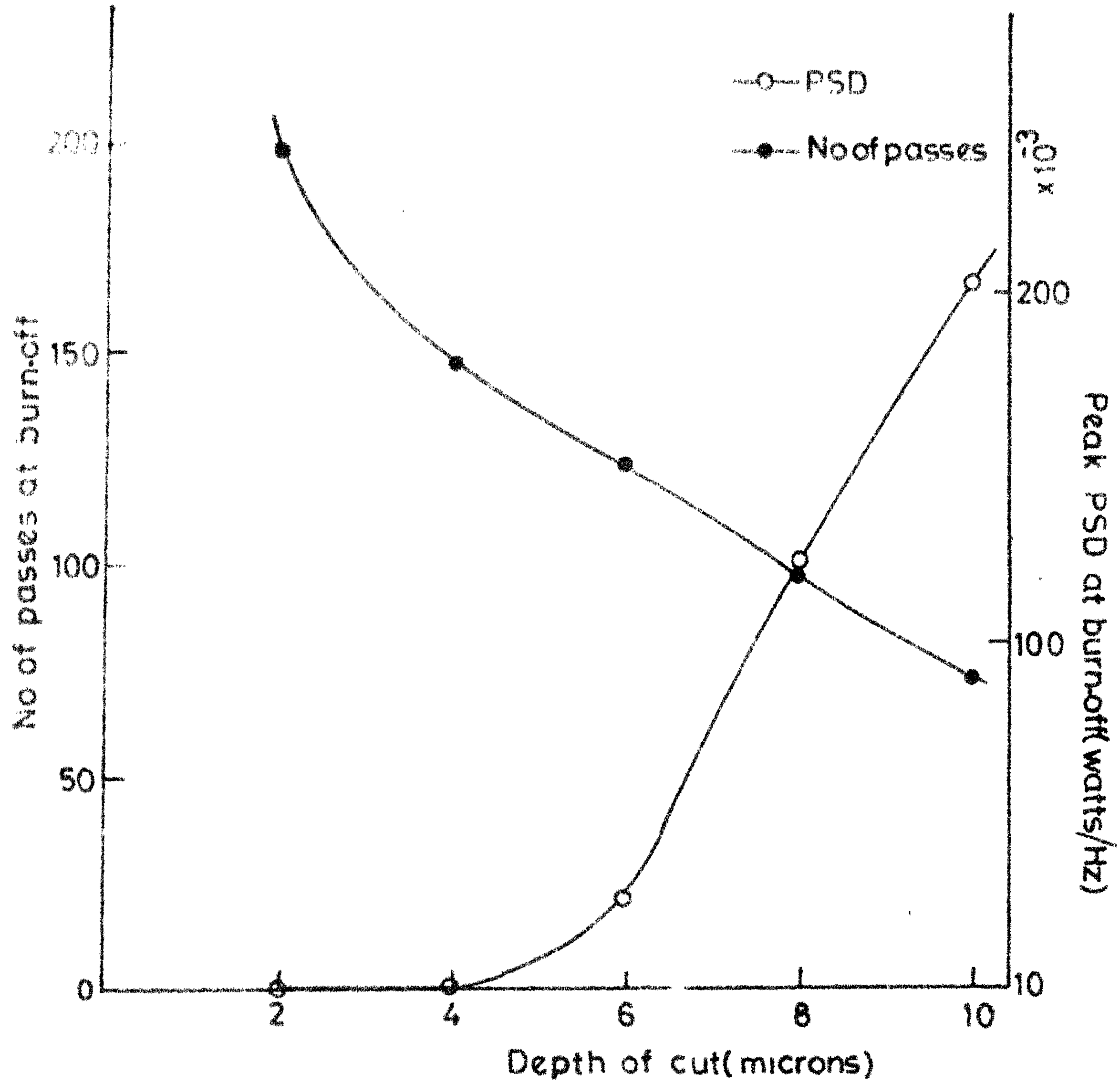


FIG-22 VARIATION OF NO OF PASSES AND PEAK
PEAK PSD AT BURN OFF WITH
DEPTH OF CUT

DATE SLIP

This book is to be returned on the date last stamped.